

NEAR-SURFACE CO₂ LEAKAGE MIGRATION

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RESEARCH OBJECTIVES

The ultimate failure of geologic CO₂ storage is the seepage of injected CO₂ out of the ground surface into the atmosphere, with associated potential health, safety, and environmental (HSE) risks. To evaluate (1) potential HSE risks, (2) near-surface monitoring strategies for CO₂ storage verification, and (3) the effectiveness of geologic CO₂ storage even in leaky systems, we must understand the behavior of leaking CO₂ in the near-surface environment. The objective of this research is to study CO₂ migration in the near surface environment by numerical simulation and theoretical analyses. The near-surface environment relevant to our studies is approximately ± 10 m from the ground surface and includes porous media (e.g., sediments, fractured rock, and soils), surface water (e.g., lakes, rivers, estuaries, and shallow marine environments), and the lower part of the atmospheric surface layer. We define leakage as CO₂ migration in the subsurface away from the primary target formation, while seepage is CO₂ migration across an interface, such as the ground surface or the basement wall of a building.

approach is to model simple systems with variable properties to cover a range of natural conditions. The domain for the simulations is a radial 30 m thick vadose zone with a constant leakage flux specified at the bottom and a surface rainfall infiltration recharge of 10 cm/yr.

ACCOMPLISHMENTS

Shown in Figure 1 are the near-surface fluxes and concentrations for three different leakage fluxes and a variety of system properties. As shown in Figure 1, seepage flux and concentration are most sensitive to the strength of the leakage source. Note that concentrations can be quite large even for fluxes that are not much larger than a typical biological flux. From our theoretical studies of CO₂ entry into surface water, we found that ebullition and bubble flow will be the dominant form of transport of CO₂ leakage in shallow surface water.

SIGNIFICANCE OF FINDINGS

The finding that small fluxes can lead to relatively large CO₂ concentrations in the shallow subsurface points to the utility of monitoring the subsurface for anomalous CO₂ concentrations. As for surface water, ebullition appears to be the expected process, making seepage detection in surface water relatively simple because bubbles are easy to detect by visual and acoustic methods. Our results suggest that once CO₂ is in the near-surface environment, it will tend to seep to the atmosphere. If seepage fluxes are small, integrated measurement and modeling strategies will be needed for CO₂ storage verification, in order to discern weak leakage and seepage signals from natural background variability.

RELATED PUBLICATIONS

- Oldenburg, C.M., and A.J.A. Unger, Coupled vadose zone and atmospheric surface-layer transport of CO₂, *Vadose Zone Journal*, 3, 848–857, 2004. LBNL-55510.
Oldenburg, C.M., J.L. Lewicki, and R.P. Hepple, Near-surface monitoring strategies for geologic carbon dioxide storage verification, Berkeley Lab Report LBNL-54089, October 2003.

ACKNOWLEDGMENTS

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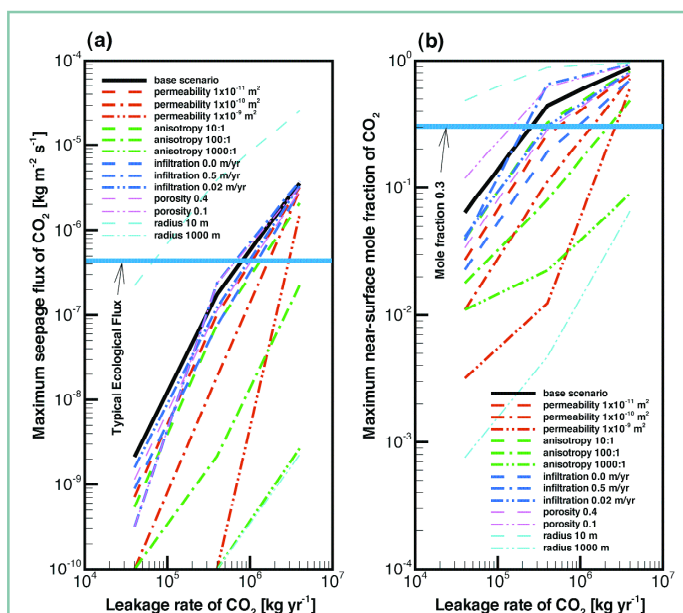


Figure 1. (a) Maximum seepage flux of CO₂ and (b) near-surface gas-phase mole fraction of CO₂ as a function of leakage rate at steady-state seepage conditions for three leakage fluxes and a variety of vadose zone properties.

APPROACH

We have developed and applied T2CA, a TOUGH2 module for simulating CO₂ and air in the near-surface environment. In addition, we have used solubility models and related theoretical analyses of ebullition potential of CO₂ in NaCl brines to evaluate the process of CO₂ entering surface water from below. Our